# Development of a Cavity Resonance Monitoring System for RAON SCL3

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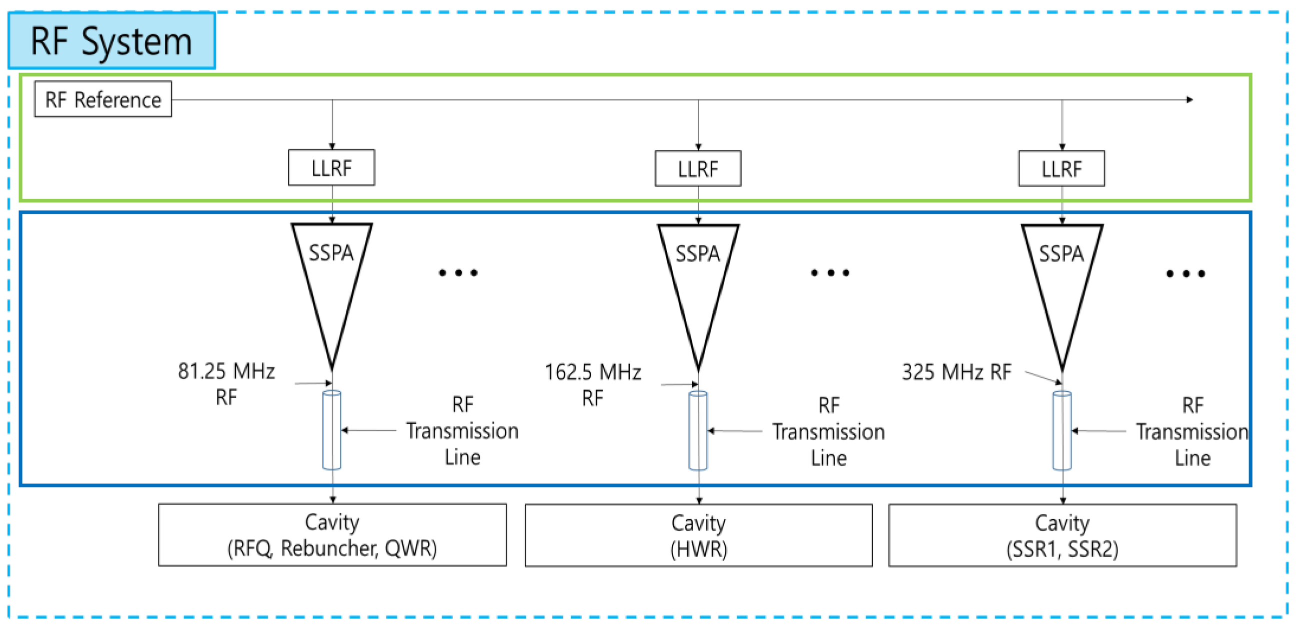
## *Abstract*

**Recently the accelerator operation for user beam service are planned in 2024. The SCL3 RF operating frequency are 81.25 MHz and 162.5 MHz. All cavities are controlled independently for the acceleration of the various A/q ions. Because all RAON SCL3 cavities are the superconducting cavities and the planned beam current is not so high, the control bandwidth which is defined by the loaded Q of the power coupler are not so wide and the suppression of the microphonics is one of the important topics for the stable operation. There are a slow cavity resonance frequency drift caused by the long-term LHe pressure drift, fast cavity resonance frequency fluctuation caused by short-term LHe pressure variation or mechanical vibration transferred through the ground. It is required to measure the shifted cavity resonance frequency and to suppress such microphonics which affects the stable RF operation. We developed a cavity resonance monitoring system for RAON SCL3.**

**The shifted cavity resonance frequency is measured and stored by the LLRF. Also a python based tool to transfer and to analyze this data is developed. In this presentation the status and test result of cavity resonance monitoring system for RAON SCL3 will be described.**

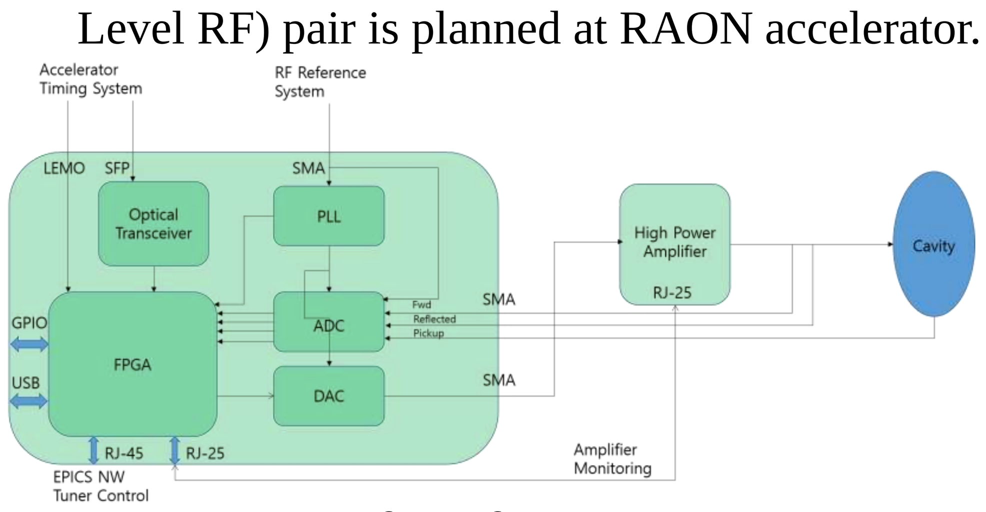
## RAON RF CONTROL SYSTEM




**Layout of RAON RF System**

**Installed LLRF**

- For the RF control of 1 cavity, 1 SSPA(Solid State Power Amplifier / 1 LLRF (Low Level RF) pair is planned at RAON accelerator.




**I/O Interface of RAON LLRF**

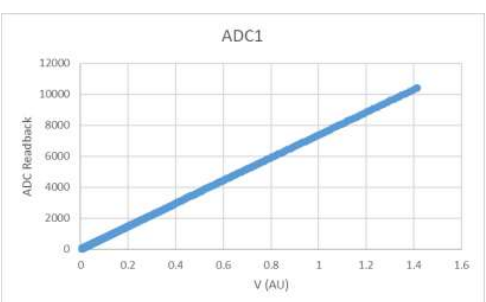
**RF System Summary**

| | Cavity | Number (EA) | f (MHz) | Power (kW) |
|---|---|---|---|---|
| SCL3 | RFQ | 2 | 81.25 | 80 |
| | Rebuncher | 3 | 81.25 | 20,15,4 |
| | QWR | 22 | 81.25 | 4 |
| | HWR | 102 | 162.5 | 4 |

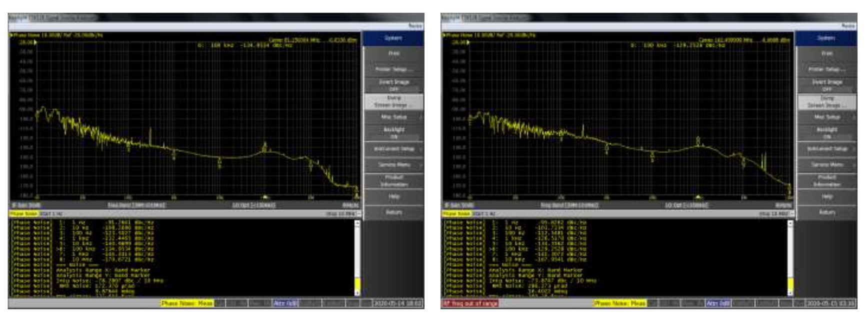
## LLRF FOR RAON SCL3

| Item | Spec |
|---|---|
| RF Input | 4 |
| RF Output | 1 |
| RF ADC | AD9653(16 bit, 4 ch, LVSD) |
| SoC | Xilinx Zynq Ultrascale ZU9EG |
| EPICS IOC | In Arm core of Zynq |
| Clock Gen | LMK04828 PLL |

- With PLL circuit, the sampling of ADC, DAC/clocking of FPGA can be changed easily.
- One hardware can support any cavity in SCL3 (low energy, 81.25 and 162.5 MHz) and SCL2 (high energy, 325 MHz)
- Generator-Driven mode and Self-Excited Loop algorithm have been implemented and being tested.

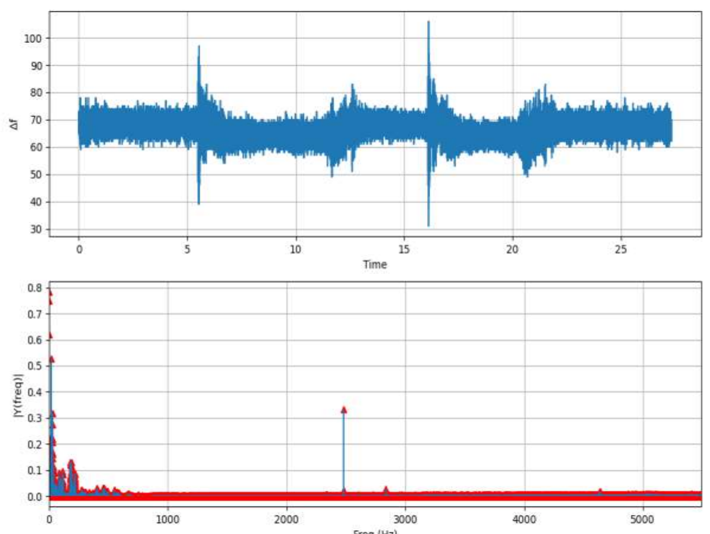



**ADC Linearity Test**
**($P_{in}$ = +3 ~ -40 dBm)**

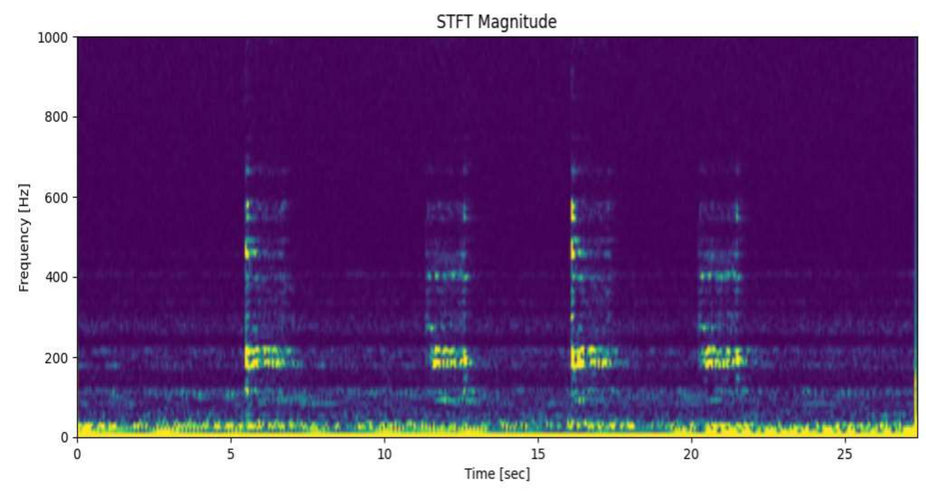


**DAC Test @81.25 MHz, 162.5 MHz**
**RMS Jitter < 0.29 mdeg**

## CAVITY RESONANCE MONITORING SYSTEM

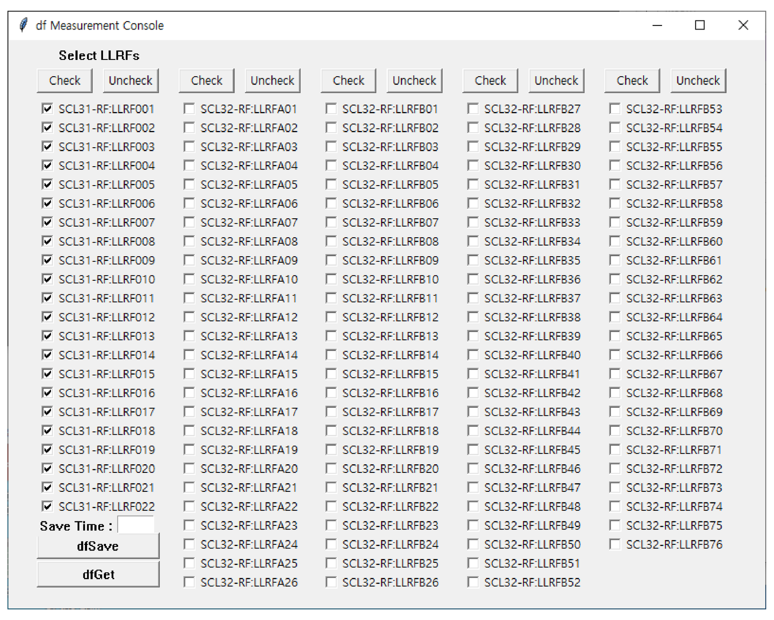


**Top : Δ frequency vs time**
**Bottom : FFT result**

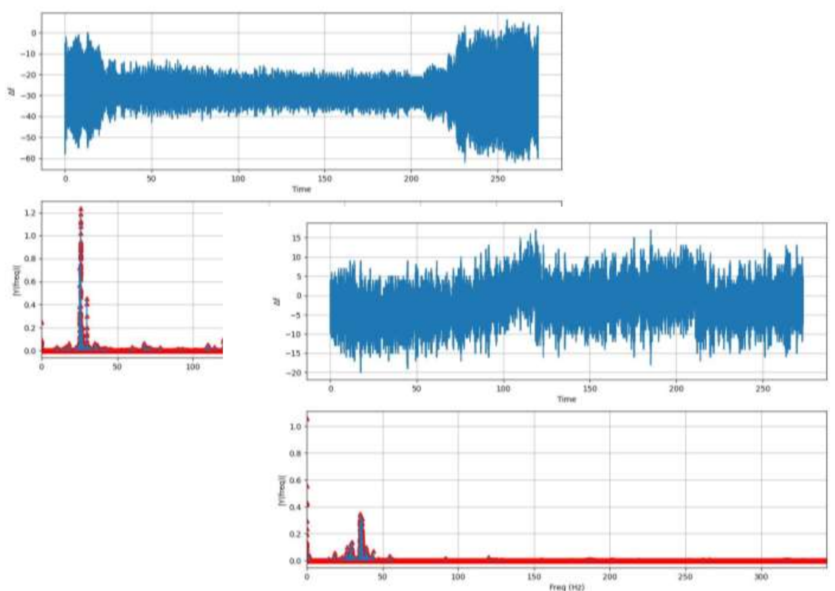



**STFT result**

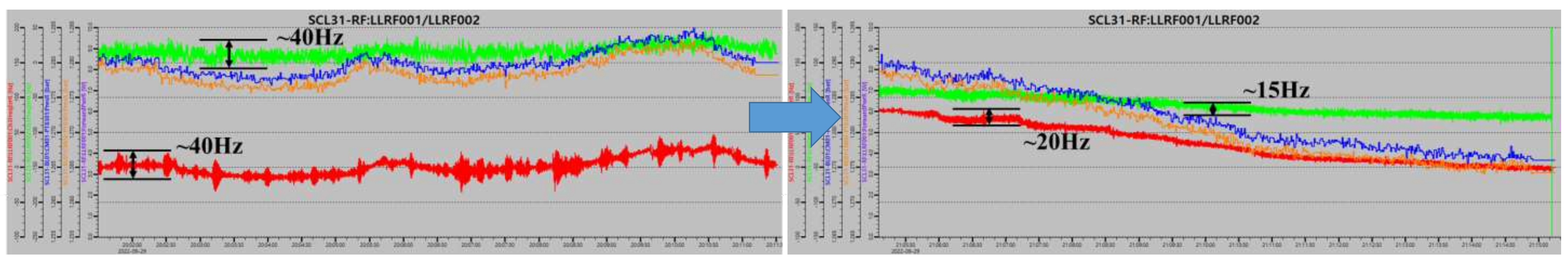
- Microphonics occurred in SCL3 were measured by the LLRF and it was used to diagnose and to reduce the it.



**Tool for frequency error measurement**



**Example of measured cavity microphonics**
**Left : HWR cavity, Right : QWR cavity**




**Microphonics mitigation (Left : before, Right : after)**

- For the operation of RF system, several tools were developed.
- For superconducting cavity, the measurement of microphonics (caused by LHe pressure fluctuation, external vibration, etc.) is important to suppress it.
- The frequency error measurement logic implemented in LLRF FPGA calculates the current resonant frequency of the cavity at sampling rate(about 10 kHz).
- Measured data are stored temporarily in DRAM of LLRF and saved as a file.
- All control (measurement trigger, duration, status, etc.) can be done by EPICS and a tool to operate this was developed by Python code.
- This tool was one of the important key for the suppression of the microphonics at RAON SCL3 accelerator and contributed for the success of the first beam commissioning and accelerator operation since 2023.

## SUMMARY

- FPGA-based LLRF has been developed and installed at RAON accelerator.
- Implementation of Digital SEL mode and Generator Driven Mode algorithm and their verification test have been performed at RAON SRF TF.
- Some functions for the SRF test (microphonics measurement, etc.) were developed and implemented and it was useful for the microphonics mitigation.
- Tool to operate this resonance monitoring system was developed and it is based on Python code.
- Developed cavity resonance monitoring system was used for the diagnostic of microphonics and it contributed for the beam commissioning of RAON accelerator.

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